- 1 1. A composite material assembly for reversibly transferring a gaseous element comprising:
- a base-material at least partially coated with a catalyst and at least partially permeable to
- the gaseous element and defining at least one hollow region for containing the gaseous
- 4 element.
- 1 2. The composite material of claim 1 wherein transferring the gaseous element comprises
- 2 releasing and/or storing the gaseous element.
- 1 3. The composite material assembly of claim 1 wherein the catalyst comprises at least one of
- 2 nickel, palladium, silver, platinum, copper, gold, titanium, silicon, iron, aluminum, indium,
- 3 gallium, niobium, tantalum, vanadium, molybdenum, tungsten, zirconium, cobalt, chromium,
- 4 carbon, cadmium, beryllium, rhenium, rhodium, rubidium, or alloys thereof.
- 1 4. The composite material assembly of claim 1 wherein a plurality of composite material
- 2 assemblies are at least one of sintered or welded together.
- 5. The composite material assembly of claim 1 wherein the base-material has a size range of
- 2 between 5 and 5000 microns.
- 1 6. The composite material assembly of claim 1 wherein the base-material comprises a
- 2 microbubble.
- 7. The composite material assembly of claim 6 wherein the microbubble has a diameter size
- 2 range between 5 and 5000 microns.
- 8. The composite material assembly of claim 6 wherein the microbubble has a wall thickness
- 2 range between 0.10 and 100 microns.
- 1 9. The composite material assembly of claim 1 further comprising at least one of aluminum,
- 2 silicon, zirconium, carbon, and boron.
- 1 10. The composite material assembly of claim 1 wherein the base-material comprises a glass.

- 1 11. The composite material assembly of claim 10 wherein the glass comprises at least one of
- vitreous silica, vitreous germania, vitreous boric oxide, titanium silicate, aluminosilicate, alkali
- 3 silicate, alkaline earth silicate, alkaline earth germinate, alkali borate, borosilicate, alkali
- 4 aluminosilicate, alkali galliosilicate, soda-lime silicate, alkali borosilicate, phosphate, natural,
- 5 and commercial.
- 1 12. The composite material assembly of claim 1 wherein the base-material comprises a glass-
- 2 ceramic.
- 1 13. The composite material assembly of claim 12 wherein the glass-ceramic comprises a
- 2 microbubble.
- 1 14. The composite material assembly of claim 12 wherein the glass-ceramic comprises at least
- 2 one of lithium aluminosilicate, lithium silicate, lithium metasilicate, lithium disilicate, zinc
- 3 silicate, and commercial.
- 1 15. The composite material assembly of claim 1 wherein the base-material comprises a ceramic.
- 1 16. The composite material assembly of claim 14 wherein the ceramic comprises a microbubble.
- 1 17. The composite material assembly of claim 15 wherein the ceramic comprises at least one of
- 2 alumina, zirconia, yttria, silica alumina, mullite, sillimanite, porcelain, and a polycrystalline
- 3 material.
- 1 18. The composite material assembly of claim 1 wherein the coating is formed by a coating
- 2 process including at least one of chemical vapor deposition, electroplating, electroless plating,
- 3 sol gel, plasma-activated chemical vapor deposition, sputtering, and painting.
- 1 19. The composite material assembly of claim 1 wherein the permeability is controllably altered
- 2 by at least one of pressure and temperature.
- 1 20. The composite material assembly of claim 1 wherein a rate of transfer of the gaseous element
- 2 is enhanced by surface modifications to the coating.

- 1 21. An electrode for reversibly transferring a gaseous element, comprising:
- a plurality of composite material assemblies each comprising an at least partially catalyst-
- 3 coated base-material, the base-material at least partially permeable to the gaseous element
- 4 and defining at least one hollow region for containing the gaseous element, wherein the
- 5 plurality of composite material assemblies is at least partially electrically interconnected.
- 1 22. The electrode of claim 21 further comprising a hydrogen-absorbing material interspersed
- 2 therewith.
- 1 23. The electrode of claim 22 wherein the hydrogen-absorbing material comprises a metal
- 2 hydride.
- 1 24. The electrode of claim 21 wherein the catalyst coating comprises at least one of nickel,
- 2 palladium, silver, platinum, copper, gold, titanium, silicon, iron, aluminum, indium, gallium,
- 3 niobium, tantalum, vanadium, molybdenum, tungsten, zirconium, cobalt, chromium, carbon,
- 4 cadmium, beryllium, rhenium, rhodium, rubidium, or alloys thereof.
- 1 25. The electrode of claim 21 wherein the plurality of composite material assemblies are at least
- 2 one of sintered or welded together.
- 1 26. The electrode of claim 21 wherein the composite material assemblies are combined to form
- 2 a non-sintered matrix.
- 1 27. The electrode of claim 21 wherein the gaseous element is hydrogen.
- 1 28. The electrode of claim 21 wherein the gaseous element is oxygen.
- 1 29. An apparatus for transferring a gaseous element, comprising:
- 2 a plurality of composite material assemblies including an at least partially catalyst-coated base-
- material, the base-material being at least partially permeable to the gaseous element and defining
- 4 at least one hollow region for storage of the gaseous element, the plurality of composite material
- 5 assemblies at least partially electrically interconnected;

- an electrolyte comprising the gaseous element; and
- 7 a power module in electrical communication with the plurality of composite material
- 8 assemblies, wherein induced electrochemical reactions involving the gaseous element,
- 9 the catalyst, the power module, and the electrolyte cause the gaseous element to either
- accumulate in or be liberated from the hollow region.
- 1 30. The apparatus of claim 29 further comprising:
- a pressurizeable environment, wherein a pressure of the gaseous element within the
- pressurizeable environment is periodically adjusted such that the gaseous element
- 4 accumulates in or is liberated from the hollow region.
- 1 31. The apparatus of claim 29 wherein the base-material is at least partially permeable to
- 2 hydrogen.
- 1 32. The apparatus of claim 29 wherein the gaseous element is hydrogen.
- 1 33. The apparatus of claim 29 wherein the apparatus is an electrochemical half-cell.
- 1 34. The apparatus of claim 29 wherein the gaseous element is oxygen.
- 1 35. The apparatus of claim 29 wherein the transfer of the gaseous element is enhanced by
- 2 chemical additions to the electrolyte.
- 1 36. A gaseous storage rechargeable electrochemical cell comprising:
- a housing;
- an electrolyte disposed in the housing and comprising a first gaseous element;
- 4 a first electrode disposed within the housing and in contact with the electrolyte, wherein
- 5 the first electrode comprises a plurality of composite material assemblies, each assembly
- 6 comprising an at least partially catalyst-coated base-material at least partially permeable
- 7 to the first gaseous element and defining at least one first hollow region for storage of the

- 8 first gaseous element, the plurality of assemblies at least partially electrically
- 9 interconnected; and
- a power module in at least partial electrical communication with the plurality of
- composite material assemblies, such that induced electrochemical reactions at the first
- electrode involving the first gaseous element, the catalyst, the power module, and the
- electrolyte, cause the first gaseous element to either accumulate in or be liberated from
- the first hollow region.
- 1 37. The electrochemical cell of claim 36 further comprising:
- a second electrode disposed within the housing in a spaced relationship relative to the
- first electrode, the second electrode comprising a second plurality of composite material
- 4 assemblies, each comprising an at least partially catalyst-coated base-material at least
- 5 partially permeable to a second gaseous element and defining at least one second hollow
- 6 region for storage of the second gaseous element, the second plurality of assemblies at
- 7 least partially electrically interconnected; and
- 8 a power module in at least partial electrical communication with the second plurality.
- 1 38. The electrochemical cell of claim 36 wherein the first gas is hydrogen.
- 1 39. The electrochemical cell of claim 37 the second gas is oxygen.
- 1 40. The electrochemical cell of claim 37 wherein the electrochemical cell is a rechargeable
- 2 battery.
- 1 41. The electrochemical cell of claim 36 wherein the first electrode comprises a mixture
- 2 including nickel as a major component, the mixture disposed on an at least partially electrically
- 3 conductive interconnected substrate that is in at least partial electrical communication with the
- 4 power module.
- 1 42. The electrochemical cell of claim 37 wherein the second electrode comprises a mixture
- 2 including nickel as a major component, the mixture disposed on an at least partially electrically

- 3 conductive interconnected substrate that is in at least partial electrical communication with the
- 4 power module.
- 1 43. The electrochemical cell of claim 37 wherein the second electrode comprises:
- a oxygen electrode disposed within the housing in a spaced relationship relative to the
- first electrode and the housing, the positive oxygen electrode on one side being exposed
- 4 through an electrolyte to the first electrode and on the opposite side to gaseous oxygen
- 5 through a supply port in the housing, the oxygen electrode including an electrode mixture
- 6 which contains an oxygen reduction catalyst present in an electrochemically active
- amount, the mixture disposed on or within an at least partially electrically conductive
- 8 interconnected substrate in at least partial electrical communication with the power
- 9 module.
- 1 44. The electrochemical cell of claim 43 wherein the second electrode is exposed to ambient air.
- 1 45. The electrochemical cell of claim 36 wherein the first electrode includes inter-dispersing a
- 2 hydrogen-absorbing material therewith.
- 1 46. The electrochemical cell of claim 45 wherein the hydrogen-absorbing material comprises a
- 2 metal hydride.
- 1 47. The electrochemical cell of claim 36 wherein the transfer of the gaseous element is enhanced
- 2 by chemical additions to the electrolyte.
- 1 48. The electrochemical cell of claim 36 wherein a rate or magnitude of side surface reactions is
- 2 controllably altered by chemical additions to the electrolyte.
- 1 49. The electrochemical cell of claim 36 wherein a rate or magnitude of side surface reactions is
- 2 controllably altered by adjustment of a cell pressure or temperature.
- 1 50. The electrochemical cell of claim 36 wherein a plurality of cells are electrically connected to
- 2 each other in parallel or series to provide or receive an increased amount of current or voltage.
- 1 51. The electrochemical cell of claim 36 wherein the electrolyte is a basic electrolyte.

- 1 52. The electrochemical cell of claim 51 wherein the basic electrolyte comprises an alkali metal
- 2 hydroxide.
- 1 53. The electrochemical cell of claim 52 wherein the basic electrolyte comprises potassium
- 2 hydroxide.
- 1 54. The electrochemical cell of claim 51 wherein the basic electrolyte is at least one of a liquid or
- 2 a gel or a solid.
- 1 55. The electrochemical cell of claim 36 wherein the electrolyte is an acidic electrolyte.
- 1 56. The electrochemical cell of claim 55 wherein the acidic electrolyte is at least one of a liquid
- 2 or a gel or a solid.
- 1 57. The electrochemical cell of claim 36 wherein the electrolyte is circulated within the housing
- 2 using a pump.
- 1 58. The electrochemical cell of claim 36 comprising a conductive matrix that includes at least
- 2 one composite material assembly in contact with or comprising at least one of conductive foam,
- 3 metal wire mesh, perforated metal foil, metal gauze, metallic foam or felt, and a perforated
- 4 metallic sheet.
- 1 59. The electrochemical cell of claim 58 wherein the conductive matrix includes a conductive
- 2 material additive comprising at least one of nickel, copper, carbon, silver, or alloys, mixtures, or
- 3 compounds thereof.
- 1 60. The electrochemical cell of claim 58 wherein the conductive matrix includes at least one of
- 2 sintering or welding constituents together.
- 1 61. The electrochemical cell of claim 36 wherein an operating temperature within the housing is
- 2 periodically maintained between -50 degrees Celsius and 1000 degrees Celsius.
- 1 62. The electrochemical cell of claim 36 wherein an operating pressure within the housing is
- 2 periodically maintained between 1 Bar and 2000 Bar.

- 1 63. The electrochemical cell of claim 36 wherein the housing further comprises a demister.
- 1 64. A method of gaseous element transfer comprising:
- 2 providing a composite material assembly including a base-material at least partially
- 3 coated with a catalyst and at least partially permeable to the gaseous element, defining
- 4 one or more hollow regions;
- 5 transferring a gaseous element into or out of the hollow region.
- 1 65. The method of claim 64 wherein the composite material assembly is a part of an
- 2 electrochemical cell.
- 1 66. The method of claim 64 wherein the composite material assembly comprises hollow glass
- 2 microspheres at least partially permeable to the gaseous element.
- 1 67. The method of claim 64 wherein the composite material assembly is at least partially
- 2 disposed in an electrolyte.
- 1 68. The method of claim 64 wherein the transfer of gaseous element is facilitated with an
- 2 electron source or sink.
- 1 69. The method of claim 64 wherein the permeability is controllably altered by chemical
- 2 additions to the base-material.
- 1 70. The method of claim 64 wherein the permeability is controllably altered by operational
- 2 changes to at least one of a pressure or a temperature about the composite material assembly.
- 71. The method of claim 64 wherein a rate of the gaseous transfer is enhanced by surface
- 2 modifications to the coating.
- 1 72. The method of claim 64 wherein electrical energy is generated by transfer of the gaseous
- 2 element from the one or more hollow regions and subsequent consumption of the gaseous
- 3 element in electrochemical reactions.

- 1 73. The method of claim 64 wherein electrical energy is consumed by transfer of the gaseous
- 2 element to the one or more hollow regions, subsequent to the gaseous element being generated in
- 3 an electrochemical reaction.
- 1 74. The method of claim 65 wherein electrical energy and water are generated by the cell
- 2 operating when the hydrogen and the oxygen are consumed in the electrochemical reactions
- 3 upon being liberated from the hollow regions.
- 1 75. The method of claim 65 wherein electrical energy and water are consumed by operation of
- 2 the electrochemical cell, at least one of hydrogen and oxygen being generated in an
- 3 electrochemical reaction and accumulated in the one or more hollow regions.
- 1 76. The method of claim 64 wherein the composite material assembly is pressurized with
- 2 gaseous hydrogen to an absolute pressure between 1 Bar and 2000 Bar.
- 1 77. The method of claim 64 wherein the composite material assembly is pressurized with
- 2 gaseous oxygen to an absolute pressure between 1 Bar and 2000 Bar.
- 1 78. The method of claim 64 further comprising periodically maintaining an operating absolute
- 2 pressure within electrolyte surrounding the composite material assembly between 1 Bar and 2000
- 3 Bar.
- 1 79. The method of claim 64 wherein periodically induced electrochemical reactions are
- 2 controlled by periodic electrical communication between an electrode and a power module.

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